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The use of mobile-assisted virtual reality in fear of darkness therapy

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Abstract

Fear of darkness is a common psychological problem that may extent to a specific phobia if it is not treated well. Several intervention techniques related to fear and phobia using actual exposure therapy have been studied for decades, however, there were some constraints emerged when the therapist provides a real environment to overcome the patient's reaction to his/her specific fear. Virtual reality (VR) technology is an innovative tool providing a more immersive, secure, personal, and controlled virtual environment. Therefore, we developed a novel framework for treating the fear of darkness named Mobile-assisted Virtual Reality (MAVR). The purpose of this study was to evaluate the use of MAVR to treat fear of darkness based on usability, time consumption and its ability to decrease fear. We used the GOMS model as an interaction guidance between human and computer which aimed to facilitate the process of re-learning in mindset change and individual's behavioral toward situation of darkness and night. Therefore, a comprehensive evaluation was conducted to measure the efficacy of the MAVR. We developed the usability assessment checklist to assess the feasibility and acceptability of the MAVR, and fear of darkness thermometer to measure the degree of fear. The Wilcoxon Signed Rank Test showed that the fear of darkness was significantly decreased after participants received the MAVR therapy (z=-3.550, p-value<0.001). We found that the MAVR was very useful, easy to be used and acceptable for participants. In conclusion, this study highlights the efficacy of Mobile-assisted Virtual Reality in treating specific fear, and it seems that Virtual Reality technology has a promising benefit to be implemented for other fear or specific phobia and also used in other psychological treatment.

Keywords: *fear of darkness, mobile-Assisted, therapy, virtual reality*

1. Introduction

Virtual Reality (VR) technology has been increasingly developed and implemented for several purposes in the last two decades, such as education, entertainment, engineering and healthcare. The current development of VR technology used in the field of psychotherapy that has several promising benefits, namely its effectivity and efficacy to treat several fear, specific phobia and some psychological problems. VR technology presents a real environment in the virtual environment which can be a promising alternative to Real Exposure therapy. The earliest prototype of visual virtual environment with stereoscopic views is Sensorama that introduced by Norton Healing in 1962 [1]. Furthermore, the next invention was the used of Head-Mounted Display (HMD) to achieved better render virtual environment for each eye through a stereoscopic binocular glasses [2]. In general, Virtual reality technology classified into three groups, namely: desktop virtual reality, immersive virtual reality, and simulation virtual reality [3]. Based on the platform, virtual reality can be grouped into mobile-based VR and desktop-based VR [4]. Previous studies showed that the use of VR technology can be more precision to solve real problems in the field of education and training [2], and also research for psychological therapy [5].

One of a common psychological problem is an extensive fear to any specific object or situation, which may lead to a specific phobia. Fear of darkness is one of the prominent problem

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in general population that can be defined as a natural fear to darkness, however some people may have an extreme fear to darkness condition. Diagnostic and Statistical Manual of Mental Disorders (DSM) V explained that person who suffer a great fear from a specific situation can be recognized as phobia [6]. The terminology of darkness can be related to night or dark environment [7], and previous studies on social science found that the night or dark situations may affect fear filling [8, 9]. This specific fear has influenced human functioning in their daily life, therefore it needs a serious intervention program.

A large number of treatment programs using Real Situation Exposure have been developed and analyzed to treat fear and specific phobia. For example, Cognitive Behavior Therapy found to be successfully reduce the fear associated with certain object or situation rather than imaginal exposure therapy [10, 11]. Nevertheless, it has concerns on its cost and the ability of therapist to handle the fear reaction of the clients/participants. The advancement of technology introduces virtual exposure therapy method that found to be useful and effective [12]. Virtual Reality Exposure Therapy (VRET) has been increasingly applied in treating individuals with specific phobias, due to its efficacy and cost effectiveness [5], [10], [13].

The concept of virtual reality for a specific phobia has been found to be useful to treat specific phobias, such as fear of flying, fear of heights, fear of being in certain situations (i.e. a dark barn, an enclosed bridge over a river, and in the presence of an animal, and in a dark room), and fear of public speaking [14]. The apparatus used in those previous studies were head-mounted display and desktop computer, therefore it was expensive, less personal, not portable, and usually placed in the office of the therapist. To response the urgent need to overcome the previous limitations, the current technology advancement has been directed to a mobile based technology. Therefore, we developed the treatment framework using the Mobile-Assisted Virtual Reality (MAVR) which handier, user friendly, and cost effective. For example, Lindner reinforced that using of consumer VR devices such as Samsung Gear and Oculus Rift allows wider use of VRET [15]. Moreover, the rapid development of smartphone technology has provided a much better graphics computing tool and more affordable than previous technology. By using tablet or smartphone, the WeaVR system succeed to decrease the cost and size of VR technology from $45,000 with weight 10.9 kg to $1,300 with weight 2.3 kg [16]. However, the hardware specification of mobile virtual reality has lower capacity than desktop virtual reality. Furthermore, the use of VR tools that are too long will cause symptoms of cyber-sickness [17]. Hence, the purpose of this study was to evaluate the use of MAVR to treat fear of darkness based on usability, time consumption and its ability to decrease fear.

2. Mobile-Assisted Virtual Reality (MAVR) Application Framework

The MAVR application framework used the Cognitive Behavioral Therapy (CBT) technique with vivo exposure method to treat individual with a fear of darkness. The framework was designed in a collaborative treatment approach whereas the therapist directed the participant in the treatment process according the procedure of protocol, and the participants invited to communicate with the therapist and familiarized his/her self to the MAVR application and apparatus (T1=adaptation with the application, T2=read the control instruction, and T3=read the simulation instruction). After they understood how to use the MAVR application, participants were asked to try the application several times before they started the real intervention. The MAVR framework used is shown in Figure 1 that consists of the therapy method that aimed to decrease the fear of darkness, and evaluation method that used to assess the usability of application and the time consumed. The CBT method framework was composed by task analyses and protocols. To assess the fear of darkness different between the baseline condition and after treatment condition, we conducted the pre-test and post-test using the fear of darkness thermometer.

In the current study, we used the Goal, Operation, Method, Selection Rule (GOMS) model to predict the interaction between human and machine that has been found as a familiar and effective measurement model [18-19]. In addition, the GOMS model can also predict the ideal time consuming while the participant is using the application, therefore we can minimized the symptoms of cyber-sickness [17], [20].

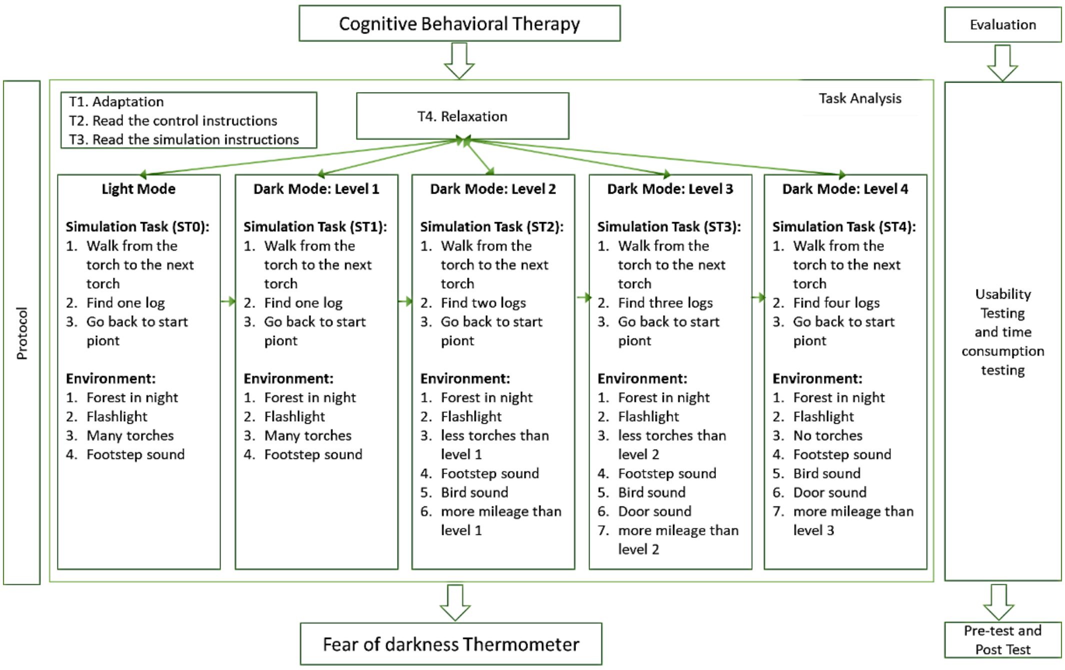

Figure 1. MAVR framework for treating the fear of darkness

The task analysis was based on the GOMS model to characterize the procedural knowledge from a user/participants when using the MAVR treatment application. We used the Cognitive Calculator (Cogulator) software to measure the mental or temporal workload of memory [21]. Based on our experimental study, we modified a 'search' operator in Cogulator to search an object in 360 degree experiences and put in 2500 milliseconds to finish that task. The GOMS model for task (T2): Read the control instructions is shown in Table 1. The participant started to search the text "'Control Instructions" in 360o view of virtual environment. After that, the participant asked to accomplish three sub goals, namely: read the direction instruction, read the action instruction, and read the relaxation instruction. The total completion time for T2 was 15.49 seconds. Every level in the simulation task was ideally designed to be accomplished less than 4 minutes.

Table 1. GOMS Model for Task 2: Read the Control Instructions

Top-level method (15.49 s) Method for Goal: Read the control instructions
Step 1: Search 'Control Instructions' (2.5 s) Step 2: Accomplish Goal Read the direction instruction (3.67 s) Step 3: Accomplish Goal Read the action instruction (4.66 s) Step 4: Accomplish Goal Read the relaxation instruction (4.66 s)
Method for Goal: Read the direction instruction (Total time = 3.67 s) Step 1: Look at 'red box' (1.1 s) Step 2: Proofread 'Moving characters during simulation' (1.32 s) Step 3: Think to understand the instruction related to the direction key (1.25 s)
Method for Goal: Read the action instruction (Total time = 4.66 s) Step 1: Look at 'blue box' (1.1 s) Step 2: Proofread 'button to select or open the map' (2.31 s) Step 3: Think to understand the instruction related to the A key (1.25 s)
Method for Goal: Read the relaxation instruction (Total time = 4.66 s) Step 1: Look at 'green box' (1.1 s) Step 2: Proofread 'button to open relaxation menu during simulation' (2.31 s) Step 3:Think to understand the instruction related to the X key (1.25 s)

First, the storyboard was constructed to visualize the asset and sound effect in virtual environment. Forest environment was chose as a map to represent the darkness situation. The map was built with the same design for every level that aimed to make the user familiar and standardized the level of fear stimuli. However, we made variations in the number of logs, torches, birds' sound and house objects for each level. The current VR application only facilitated one exit feature in Menu page, therefore the user cannot quit during the simulation task and asked to find the amount of target logs and come back to the starting point. This feature was designed to facilitate the participant to face his/her fear and adapted with the situation.

Second, the protocol consisted of introduction section, relaxation instructions, and application entry guidelines. The protocol was designed to create a comfortable atmosphere between the participant and therapist through this interactive communication. This protocol could be embedded into the VR application, so the application could be a self-treatment tool.

Third, the Sutcliffe's heuristic evaluation used to assess the usability for MAVR case that consisted of 12 points assessment of human-computer interaction in VR application [22]. The usability testing process was described in the Figure 2.

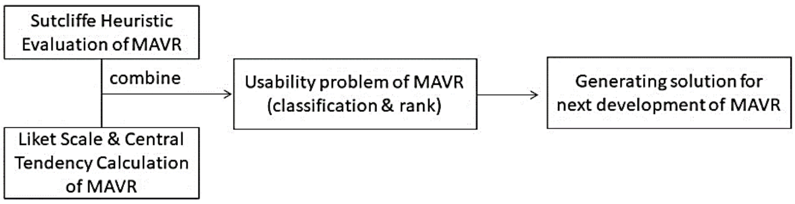

Figure 2. The usability process MAVR usability testing

The first step of the usability testing process was the respondents asked to give marks for each aspect based on Likert scale which ranged from 1 (the worst value) until 5 (the best value). Then, the central tendency was calculated as the average number from each aspect. The aspect with the central tendency value≥3.50 described that all participants agreed on the statement, and if the central tendency value<3.50 described that all participants not agreed [23]. In addition to the central tendency, the respondents also gave comment about how they felt and problems experienced during the used of the MAVR. Those experienced problems then classified into usability problem included the rank of each problem to identify the urgency level of the problem to be solved. The rank of the usability problem ranged from 1 (no usability problem) until 4 (disaster) [22]. The final step of the usability testing was classifying the usability problem into VR features based on four-point scale (severe, annoying, distracting and inconvenient) in order to determine the recommendation of the solution [22].

3. Research Method

3.1. Participants, Procedure and Measurement

The current study used one group pretest-posttest experimental design that aimed to evaluate the effect of the treatment [24]. Participants were obtained through screening procedure among undergraduate students at the Faculty of Psychology, Universitas Padjadjaran who showed the level of fear>5 on the Fear of Darkness thermometer. We distributed 130 Questionnaires and 30 participants were met the inclusion criteria and eligible to be included as the study participant. Among 30 participants, 9 of them didn't finish the treatment because they experienced headache and nausea after several minutes using Virtual Reality Application. Therefore, 21 participants finished the experiment and included in the data analysis. Fear of darkness was measured using the Fear Thermometer questionnaire that consists of individual's evaluation about their fear of darkness. Participants were asked to fill in the scale before and after the intervention. The scale ranged from 0 (no fear at all) until 10 (extremely fear). Participants underwent the MAVR at the Laboratory Room at the Faculty of Psychology, and after they finished they asked to fill in questionnaires about the usability and acceptability of the MAVR. Participant received relaxation instruction to make them more comfortable and relax before they get in to the MAVR application. The MAVR application constructed in a form of arcade game that was started from daylight to the night, whereas the light was slowly reduced during the intervention process.

We used descriptive statistic and Wilcoxon Signed Rank Test to evaluate the fear of darkness difference before and after the treatment, all statistical analyses were conducted using the SPSS version 24.0.

3.2. Hardware and Software

In the current study, we used the minimum specification of hardware to run the MAVR properly namely: Samsung Gear VR as head mounted device, wireless headphone for high definition audio, wireless Joystick for controlling the MAVR and the smartphone with minimum specification described in Table 2. The cost of all those devices is not more than $2500 when it was developed in 2017.

Table 2 Smartphone Specification for Implementing MAVR.

Variable	Specification
Dimension	143.4 x 70.5 x 6.8 mm (5.65 x 2.78 x 0.27 in)
Display Type	Super AMOLED capacitive touchscreen, 16M colors
Display Size	5.1 inches, 71.5 cm2 (~70.7% screen-to-body ratio)
Resolution	1440 x 2560 pixels, 16:9 ratio (~577 ppi density)
Operating System	Android 5.0.2 (Lollipop)
Chipset	Exynos 7420 Octa
CPU	Octa-core (4x2.1 GHz Cortex-A57 & 4x1.5 GHz Cortex-A53)
GPU	Mali-T760MP8
Internal Memory	32/64/128 GB, 3 GB RAM
Sound	3.5mm jack, Active noise cancellation with dedicated mic
Features	accelerometer, gyro, proximity, compass,
Battery	Non-removable Li-Ion 2550 mAh battery

4. Results and Discussions

4.1. Effect of Virtual Reality to Decrease Fear of Darkness

The Wilcoxon Signed Rank Test showed a statistically significance difference between fear of darkness pretest score and posttest score after participants received the MAVR therapy ($z=-3.550$, p-value<0.001). This result indicated that MAVR treatment could decrease individual's fear of darkness, significantly. The result of the current study is in concordance with previous studies, whereas VR was found to be effective in treating patients with specific phobias such as fear of flying [25], fear of height [26, 27], and acrophobia [28]. Literatures stated that the aim of the intervention using the Virtual Reality was to decrease the anxiety by conducting exposure to a similar situation that make them anxious/fear. The core principle in this intervention is exposure. The result of the current study showed that the MAVR invention on the psychotherapy setting could give contributions to the clinical psychology practice, this is an innovative intervention method that can be used to treat patients with fear of darkness or other fear/specific phobia. This study set up an ideal protocol for the treatment procedure, whereas individual who had fear of darkness trained to do relaxation until they master it, therefore they got into the treatment through a set of MAVR application.

Participants will be first treated with relaxation to reduce his/her anxiety. After that, they will be asked to face the situations that make them anxious, starting with situations that stimulates the lowest anxiety and gradually increase to the situation that stimulates the highest anxiety. The Use of Virtual Reality as the intervention has been confirmed to be more beneficial for participants and also therapist, for example at some conditions, in vivo (real) exposure is impractical, difficult and potentially dangerous (e.g. driving phobia) and also expensive (e.g. Flight phobia), the invention of the VR and MAVR technology in therapy can be beneficial because it is safe, handy and cost-effective. In addition, the important benefit that obtained from the VR or MAVR application compared to the real exposure is the involvement of the participants in the therapy process, participants were invited to have their own control during the intervention process, therefore it will increase their self-efficacy and self-confidence that facilitate the re-learning process toward their fearful object can be occurred effectively [14]. As mentioned in the previous literature, the purposes of using Virtual Reality as an intervention technique is a sense of presence. In fact, participants are physically immersed in the virtual environment, however the real sensation is achieved by shutting out "real world" stimuli [14]. The Virtual exposure shows in the form of 3D pictures which it can be controlled and managed by the participants. During the process they are learning to overcome their fear through relaxation technique, so whenever they feel anxious or fear, they could stop running the application and then doing the relaxation following the concept of systematic desensitization technique. With more controlled situations, their fear will decrease gradually and their sense of control toward the fearful situation is increasing. Participants become more self-efficacy and self-confidence, and they will be able to make a transfer of learning about the fearful situation in the VR to the real world.

4.2. Usability Testing

In the current study, 76% of participants had experiences playing games, so they were familiar with control device, and 24% of participants had not playing games, but they have seen the control device. Another aspect observed was the familiarity to the VR application, the result showed that is 86% of participants never used VR, and the rest of participants had used the VR at least once. Those background data included on the usability test. Experiences and participants' comments obtained from the central tendency value which is shown in Table 3 below.

Table 3. The Central Tendency Value of Each Sutcliffe's Heuristic Evaluation for the MAVR.

Aspect	1	2	3	4	5	6	7	8	9	10	11	12
Value	3.76	3.76	3.95	3.48	4.19	3.14	3.81	4.14	4.05	4.19	N/A	3.57

The highest value was 4.19, which obtained from realistic feedback and support for learning aspect. It means that respondents agreed that the MAVR had a good usability in both aspects. The MAVR application provided suitable feedback for every interaction that came from each participant. The control information, the guidance of simulation, and map in the VR supported the participants to understand the flow of the MAVR application. The lowest central tendency value was 3.14, which obtained from faithful viewpoints aspect. It means that the visual display while switching the head is less smooth. Furthermore, the variation in central tendency value was occurred due to the emergence of problems when respondents used the MAVR application. Table 4 and Table 5 describes the detail of usability problems reported by participants.

Table 4. Classification of Usability Problem that Encountered in the use of MAVR

Aspect	Rank*)	Usability Problem Encountered
Natural engagement	3	• Scaling in the map is not realistic • The flashlight reflection doesn't fit • The animation is far from real
Compatibility with the user's task and domain	2	• The game at the next level is predictable. The participants can guess where the wood is placed based on experience at the previous level
Natural expression of action	1	• The running speed of the player is very slow
Close coordination of action and representation	4	• The 3D object quality is poor and cause the dizziness
Realistic feedback	1	• There is no audio effect that informs the wood has been picked but only text
Faithful viewpoints	4	• The visual display while switching the head is less smooth causing dizziness
Navigation and orientation support	2	• Player direction information on the map is not clear • Font size in each menu is too small to be unreadable
Clear entry and exit points	-	There is no usability problem
Consistent departures	-	There is no usability problem
Support for learning	1	• There is no information in night mode level 3 about reducing the light and should follow the torch
Clear turn-taking	N/A	• Single user, so no communication between avatars
Sense of presence	1	• The owl effect is less powerful in shaping the jungle atmosphere of the night

Rank: 1: accessories, 2: minor problem, 3: major problem, 4: disaster

Table 5. Classification and the Severity Rank of the Usability Problem Based on MAVR feature

Feature	Problem Description	Severity Rating	Alternative Improvement
GrapFhic, presence	3D object motions, map scale, and game environment	Severe	The 3D object should be re-developed, map scale adjustment, and improve the game environment
Interaction	Slow speed while walking, the game is easily predicted	Inconvenient	Given two alternatives of walk: normal mode and run mode, the wood placed randomly.
Environment	The owls do not give significant effect, less information in night mode	Inconvenient	Lighting information is added to the map, the owl effect is more propagated, such as placed the eye of the owl in the tree object
Control	The font size is too small	Inconvenient	The font size should be adjusted
Hardware	The hardware is too heavy and uncomfortable	Inconvenient	Upgrading the head mounted device and the specification of the smartphone

4.3. Time Consumption Test Result

We collected data about completion time in order to evaluate the completion time needed by each user/participant to accomplish every task. Two male participants were tested (Colom R1 and R2), both of them often play digital games and have no tendency to fear of darkness. Table 6 shows a detail information of completion time for every task based on model GOMS, R1, R2, R3, and R4 classification. In the table, columns R3 and R4 represents the average time of tasks completion required by the group of male and group of female participants who had fear of darkness, respectively.

Table 6. Time Completion Comparison to Accomplish the Tasks on MAVR

Tasks	GOMS Model (s)	R1 (s)	R2 (s)	R3 (s)	R4(s)
T1. Adaptation	50	40	35	45	38
T2. Read the control instructions	15.49	9	14	88	82
T3. Read the simulation instructions	55.6	43	26	65	75
T4. Relaxation	N/A	N/A	N/A	N/A	N/A
Entry to Light Level from home scene	13.6	14	11	12	15
ST0.Time Completion for light level	233	178	176	320	282
- Found 1st log	50.0	38	37	95	110
- Found 2nd log	32.5	25	22	35	32
- Found 3rd log	47.5	38	39	42	31
- Found 4th log	50.5	37	37	55	48
- Go back to the starting point	50.0	40	41	93	61
Entry to level 1 from home scene (night mode)	13.6	11	12	13	14
ST1.Time Completion for level 1	99.5	108	89	146	109
- Found one log	54.5	44	47	58	63
- Go back to the starting point	45	64	42	88	46
Entry to Level 2 from home scene (night mode)	13.6	12	6	12	15
ST2.Time Completion for level 2	163.5	154	141	140	152
- Found 1st log	47	49	43	49	49
- Found 2nd log	38.5	30	28	25	32
- Go back to the starting point	78	75	70	66	71
Entry to Level 3 from home scene (night mode)	13.6	10	10	11	13
ST3.Time Completion for level 3	167.5	152	153	262	205
- Found 1st log	47	42	44	50	46
- Found 2nd log	34	28	25	25	29
- Found 3rd log	40	35	36	42	65
- Go back to the starting point	46.5	47	48	145	65
Entry to Level 4 from home scene (night mode)	13.6	14	11	12	11
ST4.Time Completion for level 4	233	191	202	243	295
- Found 1st log	50.0	46	43	47	50
- Found 2nd log	32.5	27	26	31	35
- Found 3rd log	47.5	35	37	38	48
- Found 4th log	50.5	47	44	50	56
- Go back to the starting point	50.0	36	52	77	106

The first simulation (ST0) and Level 4 (ST4) were designed with same map and tasks, except the level of brightness. The purpose of this level was to familiarize the user/participants with the situation and showed them that there was nothing to be worried in the dark situation. The GOMS model predicted that it took about 233 seconds to accomplish the task in the light level, or level 4 in the night mode. In fact, R1 and R2 were able to finish the task in the light level faster than in the night mode level 4. Then, the participants continued the simulation in level 1, 2, 3, and 4. In every level, the participants took a break to minimize cyber-sickness. In average, both respondents were able to finish the task faster than the ideal time from the GOMS model. In general, participants showed in R3 and R4 had longer completion time than the GOMS model or other respondents. Task 4 (T4) relaxation was suggested to all participants, however it depends on the participants whether they need it or not to take relaxation.

Based on the experiments, the performance of MAVR surprisingly compete with another similar VR application in order to decrease the level of anxiety [29]. However, several encountered performance problems which also experienced by [29, 30] should be fixed to get better functionality. Not only functionality issue, these problems also cause dizziness. But, the dizziness effect not investigation yet in this study.

5. Conclusion

This study found that the Mobile-assisted Virtual Reality (MAVR) is able to decrease a level of fear among those who experienced fear of darkness. Moreover, the usability test showed that participants reported that the VR have a good usability in realistic feedback and support for learning aspects. Nevertheless, improvement is need on several aspects, namely: close coordination of action and representation aspect. We suggest to design the MAVR application to be used maximum 15 minutes which is based on the GOMS model and to prevent side effect from cyber-sickness. This study highlights the efficacy of Mobile-assisted Virtual Reality in treating specific fear, and it seems that Virtual Reality technology has a promising benefit to be implemented for other fear or specific phobia and also used in other psychological treatment. To have a stronger evidence on its empirical efficacy, further study of the MAVR is needed to extrapolate the result of the current study.

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